# UNIT 3 - TECHNOLOGY
# SECTION 1: POWER SYSTEMS & EFFICIENCY

## Vocabulary

| | | |
|---|---|---|
| British Thermal Unit | input | resistance |
| calorie | joule | superconductivity |
| combustion heat engine | kilocalorie | thermodynamics |
| dissipate | output | watt |
| efficiency | perpetual motion | work |
| energy content | power system | |

### Power Systems

Over the course of history, humans have increasingly shifted the burden of work from themselves to machines. As cultures develop, people are able to design more machines to do more things, and the kinds of machines they design become more complex. But a common element among all machines is the ability to convert energy from one form to another to perform useful **work**.

A **power system** converts, transmits, and controls energy to perform useful work. A machine such as a lawn mower is a relatively small power system with few parts and few end tasks. Some power systems are very large, and have many parts and end tasks. An example would be an electric power plant and transmission system, which may serve millions of people and have parts extending over hundreds of miles.

FYI

## Perpetual Motion

For hundreds of years, people have tried to create perpetual-motion devices. They have been lured by the prospect of an almost free and unlimited source of power. The first perpetual-motion machines tried to deliver more energy from a falling or turning object than would be needed to move the object back to its original position. Success in such an endeavor would result in a machine that would literally continue in motion forever.

Today, scientists try to approach the ideal of zero energy loss in a system by investigating superconductive materials that can carry an electrical current without any resistance. This means that an electric current can be passed through the material without the usual loss of energy in the form of waste heat.

Have you ever seen a portable electric heater with glowing red coils? Such heaters pass electric current through highly resistive materials. The resistive materials become so hot that they glow and give off radiant heat.

The electrical resistance of most superconductors disappears at temperatures around -250° C (-418° F). Though no energy is lost in such a system through the heat of resistance, it still takes more energy to keep the material cold than the work resulting from the superconductive electric current flow.

## Efficiency

**Efficiency** compares the **output** produced by a power system with the total energy **input** into the system. For example, to figure the efficiency of a self-propelled lawn mower, you compare the energy input *(the electricity or fuel used by the mower)* with the work output *(the speed and force of the whirling blade, the amount of ground covered, uphill travel, etc.)*

**How efficient a machine is can be expressed as a number obtained from this general formula:**

$$\frac{\text{useful output}}{\text{energy input}} = \text{efficiency rating}$$

The ideal power system would be a device that converts a readily available form of energy directly into useful work with no loss of energy, i.e., with100 percent efficiency.

Under the laws of physics as we understand them, creating a 100 percent efficient power system is impossible. Some energy is always lost in the conversion process. Nevertheless, many people have tried. Although they have not been successful, the process has led to the invention of more and more efficient machines.

The overall efficiency of a power system, large or small, depends on many factors. Sometimes a series of energy conversions occur before the energy is finally put to work. Though only a small amount of energy is lost in each conversion, the losses can add up. Simple systems eliminate some energy conversions, but the energy loss per conversion can sometimes be great. Seeking the most efficient overall way to accomplish tasks is an important goal for scientists and engineers.

People often talk about the efficiency of an individual machine such as a water heater or a furnace. But we can also talk about efficiency in a broader sense. We can take into consideration not only how the fuel or energy source is used by a machine, but also the characteristics of the energy source and the overall efficiency of the processes by which it is obtained, transported, and stored.

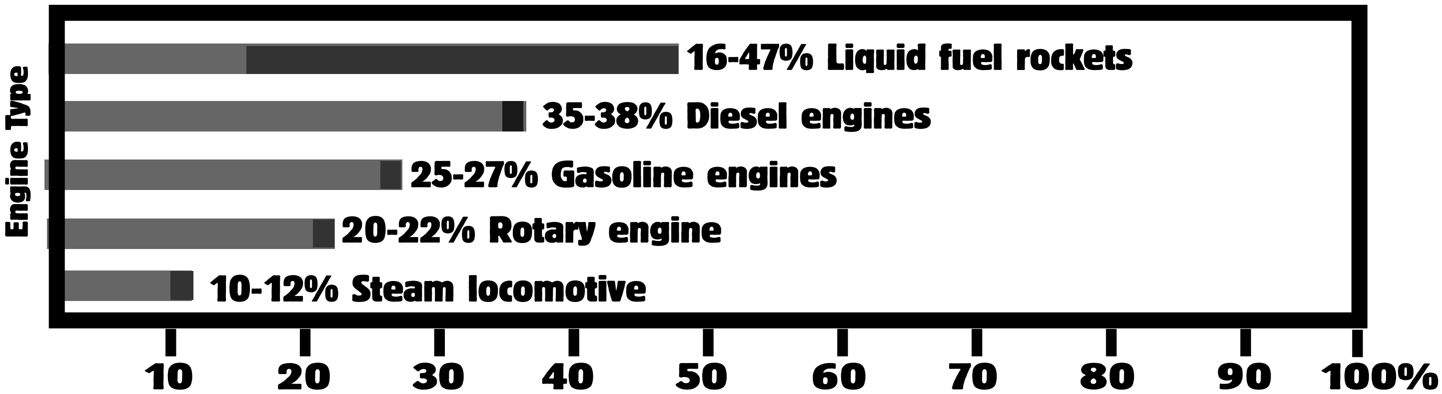



**Figure 3-1-1 Typical efficiencies of engines**
**Source: *Bosch Automotive Handbook,* 4th edition**

## Automotive efficiency

Many small power systems, including automobiles, harness the energy produced by burning fossil fuels. These converters use combustion to produce heat from fuels such as gasoline, natural gas, propane, and other materials containing carbon. For this reason, they are called combustion heat engines.

Combustion heat engines tend to be relatively inefficient, because the heat that drives the machine also tends to dissipate easily into the environment. Energy is lost in the friction of moving parts, in overcoming rolling resistance (e.g., from irregularities in the road and flexing of tires), from air resistance, and from power-train resistance. Energy is also consumed by lubrication and cooling systems, which are necessary to make sure the heat engine does not destroy itself.

The remainder of the heat is used by the engine to develop power. Because a great deal of heat is lost during engine operation, the efficiency of a gasoline engine may be as low as 15 percent and seldom is higher than 30 percent.

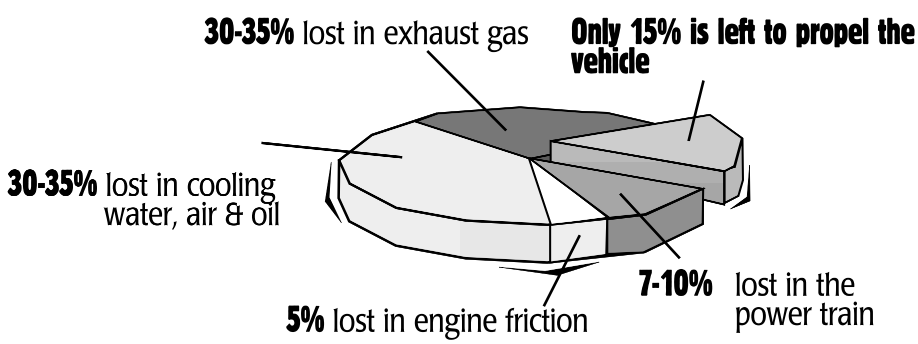



**Figure 3-1-2 Energy loss in a typical, new passenger vehicle**
**Source: *Bosch Automotive Handbook,* 4th edition**

## Measuring energy

Heat energy can be measured in **joules** (J), **calories** (cal), or **kilocalories** (kcal) (Figure 3-1-3). The joule is the unit used to measure heat in the International System of Units. One joule equals the work done by a force of one newton acting through a distance of one meter. One calorie is the amount of heat that is needed to raise the temperature of 1g of pure water 1°C. A joule is about 1/4 of a calorie. To be precise,

$$1\text{ J} = 0.239\text{ cal} \quad \text{and} \quad 1\text{ cal} = 4.18\text{ J}$$

The term Calorie (with a capital c) used in nutrition is equal to one kilocalorie (1,000 calories). So, the statement that 10g of sugar has 41 Calories means that burning 10g of sugar will produce 41 kcal of heat (energy).

The **British thermal unit** (Btu) is a larger unit than the kilocalorie. One Btu is the amount of energy required to raise the temperature of one pound of pure water 1°F. The Btu is often used in measurements of the energy produced in internal combustion machines.

Electric power is measured in **watts**. When talking about relatively large amounts of power, kilowatts (1,000 watts) are used. Kilowatt-hours, a measure of electrical energy, can be related directly to Btu (1kWh = 3,413 Btu), allowing comparisons between electrically powered systems and combustion heat systems.

## Heat energy units

| | |
|---|---|
| calorie | (cal) The amount of heat energy required to raise the temperature of 1 gram of pure water 1° Celsius. |
| Calorie | (Cal) The amount of heat energy required to raise the temperature of 1 kilogram of water 1° Celsius; 1,000 calories. |
| Btu | (British thermal unit) The amount of heat energy required to raise the temperature of 1 pound of water 1° Fahrenheit. |
| therm | A measure of heat energy defined in many different ways. The most common use is to stand for 100,000 Btu. |
| quad | (Q) 1,000,000,000,000,000 (1 quadrillion) Btu. Often used when talking about extremely large amounts of energy consumption, such as for entire countries. |

## Fuel units

| | |
|---|---|
| gallon | (gal) Measure of liquid fuel such as propane or gasoline. Approximately 3.785 liters. |
| barrel | (bbl) Measure of liquid fuel; equal to 42 gallons or about 159 liters |
| cubic foot | (cu ft or $ft^3$) Measure of a gaseous fuel such as natural gas. About 0.028 $m^3$. |
| pound | (lb) Measure of solid fuel such as wood or coal. About 0.454 kilograms. |
| short ton | (ton) Measure of solid fuel; equal to 2,000 pounds or about 0.907 metric tons. |

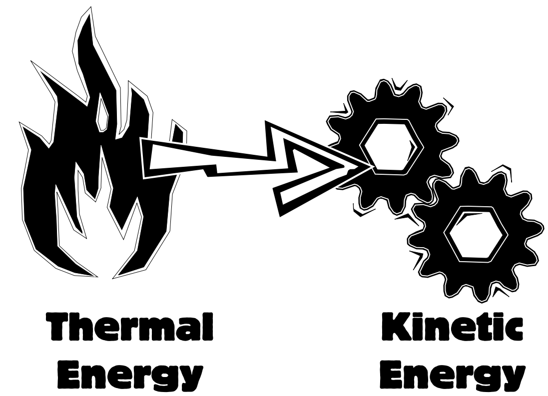
## Electricity units

| | |
|---|---|
| kilowatt | (kW) Measure of electrical power or electrical generation capacity. A kilowatt is 1,000 watts. One megawatt (MW) is the equivalent of 1,000,000 (1 million) watts; a gigawatt (gW) is 1,000,000,000 (1 billion) watts. |
| kilowatt-hour | (kWh) Measure of electric energy. A motor requiring 1 kW operating for 1 hour, or a 100-watt light bulb lighted for 10 hours, would consume 1 kWh of electricity. |

**Figure 3-1-3 Heat, fuel, and electricity units**

## Thermodynamics

Thermodynamics is the study of heat and its transformation into mechanical energy. The word stems from Greek words meaning "movement of heat."




**Whenever heat is added to a system, it transforms into an equal amount of other forms of energy.**

The science of thermodynamics was developed by Benjamin Thompson (1753-1814), an American-born British scientist. Thermodynamics is the study of relationships between heat and other forms of energy, focusing on how heat moves and the conversion of energy from one form to another. Thompson was the first to discover that heat flows from hot to cold, not the other way around, by drilling a hole in a metal ball and observing how the ball's heat was transferred to water.

When the law of conservation of energy is applied to the study of heat and its transformation into kinetic energy, it becomes the first law of thermodynamics: all the energy transferred between a system and its surroundings must be accounted for as heat and work.

If we add heat to a system, it can:

- Increase the internal energy of the system, if it remains in the system, or
- Do external work, if it leaves the system.

## Calculating efficiency

Recall that the efficiency rating of a system or machine is calculated by comparing the amount of energy input to the amount of energy output (work accomplished).

**Useful work/energy input = efficiency rating**

Finding the difference in efficiency of different fuels is complicated because the fuel volumes are measured in different ways according to their forms: solid, such as coal; liquid, such as gasoline; or gas, such as natural gas. Conversion is often required, because to be accurate, inputs and outputs must be expressed in the same units, such as Btu's (Figure 3-1-4).

| Fuel | Note | Amount | Approximate Equivalent Btu |
|---|---|---|---|
| butane | measured as pressurized liquid | 1 gal | 102,032 |
| biodiesel | | 1 gal | 129,500 |
| CNG | compressed natural gas at 3,000 psi | 1 gal | 29,000 |
| coal | bituminous | 1 lb<br>1 ton | 13,100<br>26.2 million |
| diesel | | 1 gal | 129,800 |
| electricity | | 1 kWh | 3,400 |
| ethanol (E85) | | 1 gal | 80,460 |
| gasoline | | 1 gal | 111,800 |
| kerosene | | 1 gal | 135,000 |
| LNG | liquefied natural gas | 1 gal | 73,500 |
| methanol (M85) | | 1 gal | 65,350 |
| natural gas | dry (mostly methane), uncompressed | 1 $ft^3$<br>1 therm (97 $ft^3$) | 1,032<br>100,000 |
| petroleum | crude | 1 bbl | 5.8 million |
| propane | measured as pressurized liquid | 1 gal | 84,000 |
| wood | oven-dried hardwood | 1 lb<br>1 cord (128 $ft^3$) | 8,300<br>21 million |

**Figure 3-1-4 Converting fuel units to heat units**
*This chart will help you convert amounts of electricity and common fuels to units of heat energy.*

*Source: U.S. Department of Energy; National Association of Fleet Administrators.*

Efficiency is usually given as a percentage and can be computed with the following formula:

$$\frac{\textbf{Useful output}}{\textbf{Energy Input}} = \textbf{efficiency rating x 100} = \textbf{percentage efficiency rating}$$

For example, if you ate only one apple for every two apples you were given, your eating efficiency would be calculated like this:

$$\frac{\textbf{1 apple eaten}}{\textbf{2 apples possible}} = \textbf{0.5 x 100} = \textbf{50\%}$$

## Power Systems & Efficiency Resource List

http://electron4.phys.utk.edu/141/nov17/November17.html
University of Tennessee
Animated explanation of steam engine and internal-combustion engine; links to other sites with lessons on internal-combustion engines.

http://www.howstuffworks.com/horsepower.htm
Howstuffworks.com, Inc.
Explains horsepower, torque, dynamometer testing, power-to-weight ratios; links to other sites on mechanics and automotive technology.